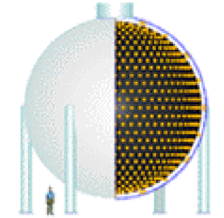


Short Baseline Neutrino Oscillations and MiniBooNE

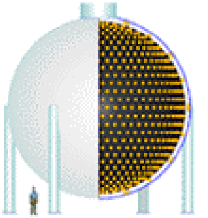
Jonathan Link

Columbia University

The 5th KEK Topical Conference – Frontiers in Flavor Physics

November 20-22, 2001

Outline



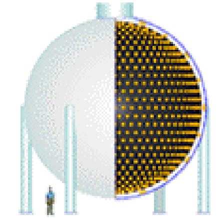
Some of you may have noticed that I'll be giving two talks.

(*Recent Results from Focus*, tomorrow at 11:00)

1. Background on Short Baseline Neutrino Oscillations
   - A little neutrino physics
   - The LSND oscillation result
2. About MiniBooNE
3. Status of MiniBooNE.

A Little Neutrino Theory

very

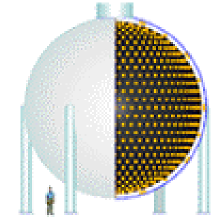


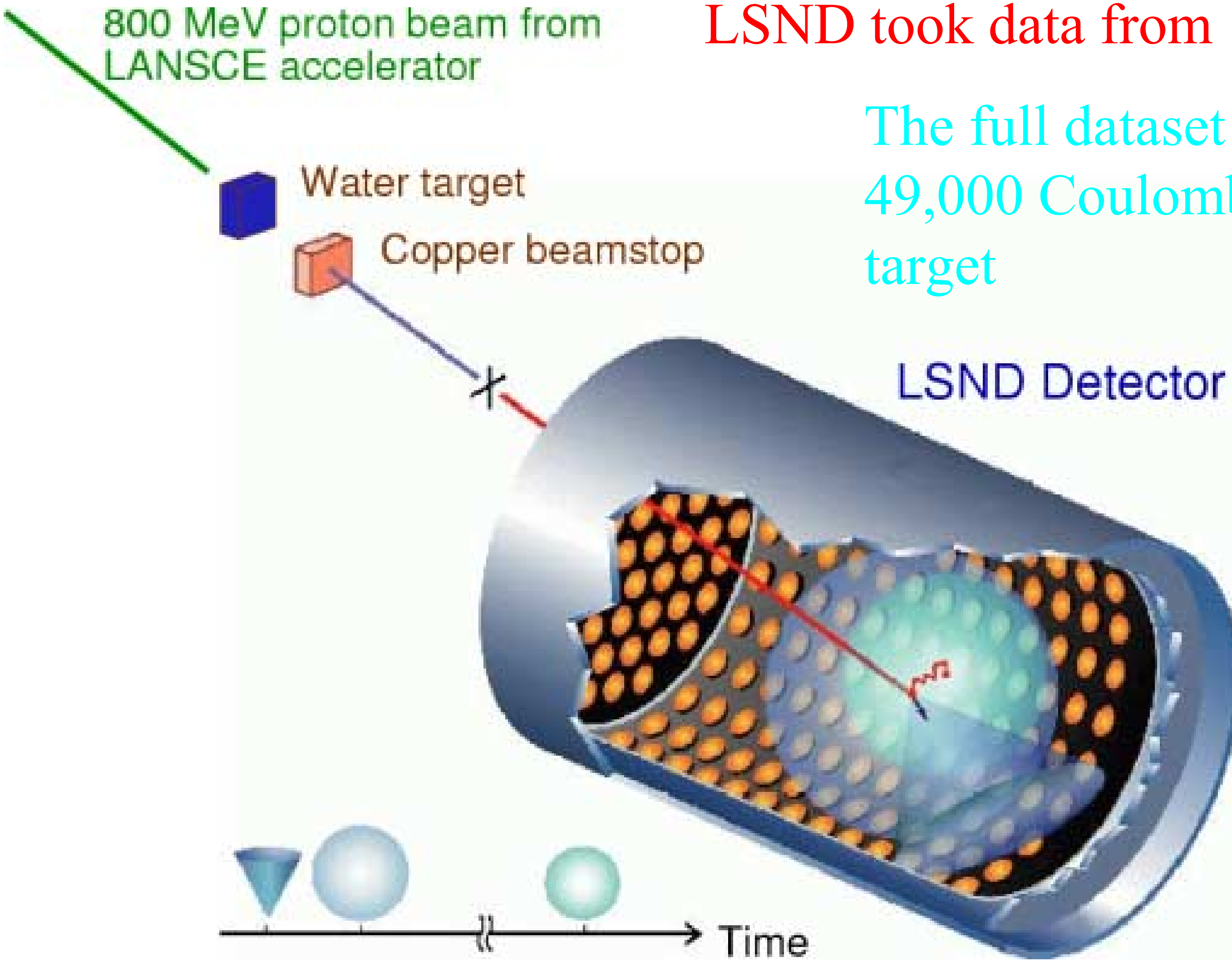
If neutrinos have mass then they may oscillate between flavors with the following probability

$$P = \sin^2 2\theta \sin^2(1.27\Delta m^2 L / E)$$

Where L is the distance that the neutrino travels (the so called baseline), E is the neutrino energy, $\sin^2 2\theta$ is the oscillation mixing angle – like a CKM matrix element for the neutrino sector – and Δm^2 is the mass difference squared between neutrino mass eigenstates.

The LSND Experiment





LSND took data from 1993-98

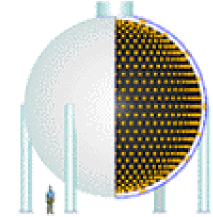
The full dataset represents nearly 49,000 Coulombs of protons on target

With a baseline of 30 meters

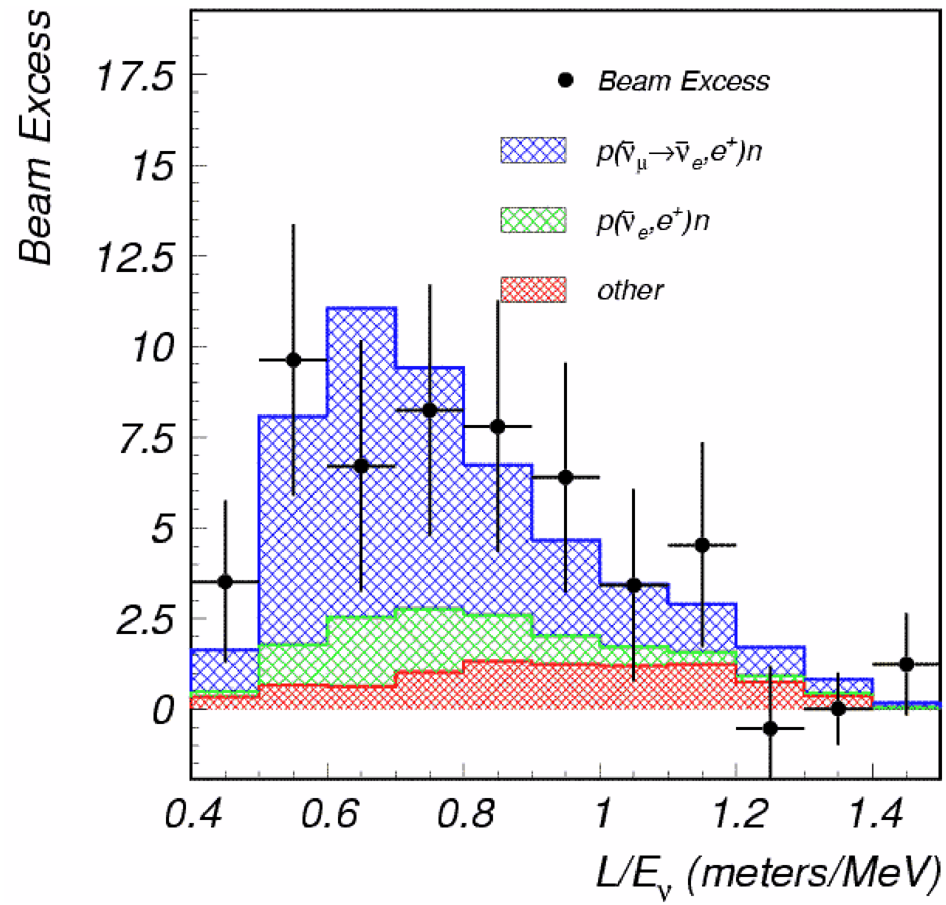
and an energy range of 20 to 55 MeV,

for an L/E of about 1m/MeV

LSND's Unexpected Result



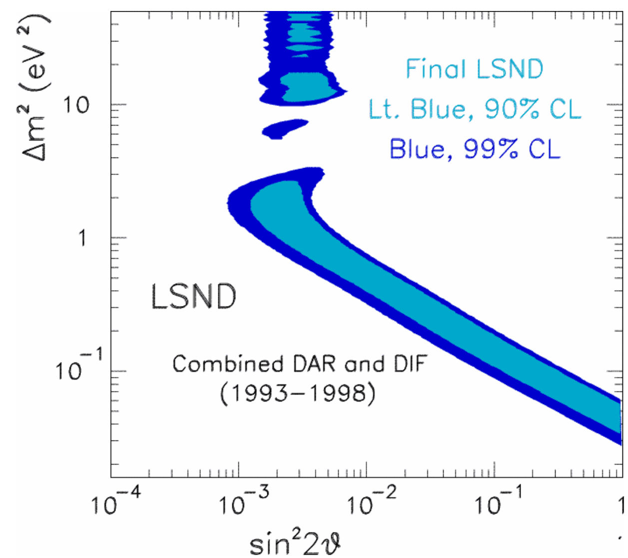
They looked for an excess of $\bar{\nu}_e$ events over the expected intrinsic $\bar{\nu}_e$ background in a $\bar{\nu}_\mu$ beam and saw...



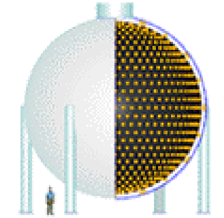
An excess of 87.9 ± 22.4 ± 6.0 events.

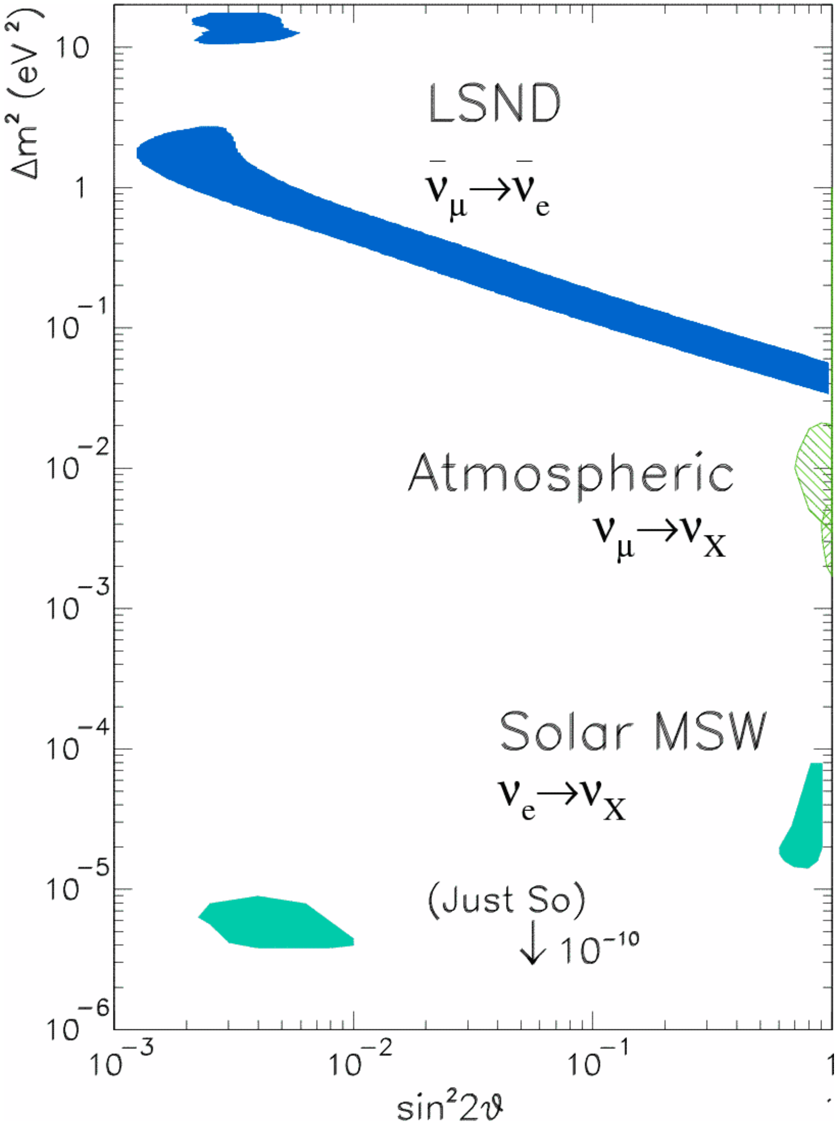
With an oscillation probability of (0.264 ± 0.067 ± 0.045)%.

3.3 σ evidence for oscillation.



Why is this result problematic?





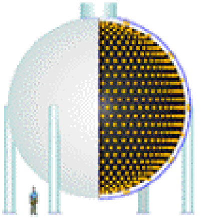
LEP proved that there are only three light neutrinos coupling to the Z^0.

Therefore there can be at most two neutrino mass difference scales.

But the oscillation results from atmospheric and solar neutrinos are well established.

If LSND is right it implies new physics such as a fourth neutrino that is sterile.

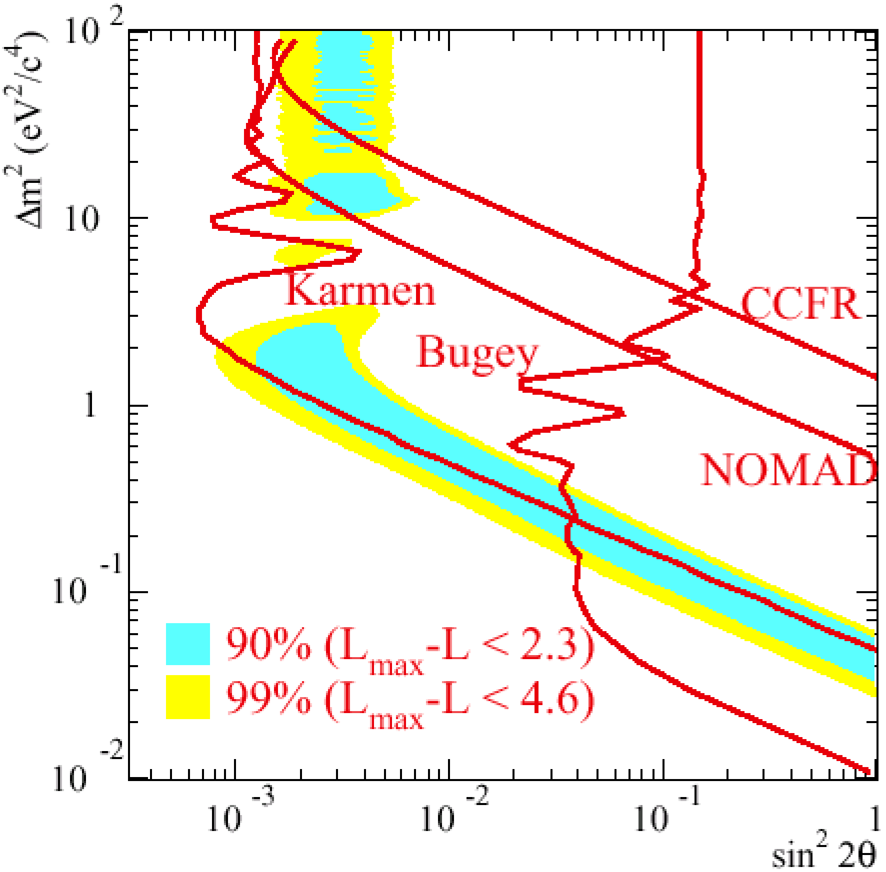
What About Karmen?



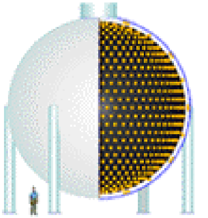
Karmen looked for an excess of ν_e events in ν_μ's from the decay of pions produced at the ISIS Spallation Neutron Source.

They saw fewer ν_e events than expected from backgrounds.

Nevertheless, there is still a large area of the LSND allowed region that is not ruled out.



The MiniBooNE Collaboration



The BooNE Collaboration

October 16, 2001

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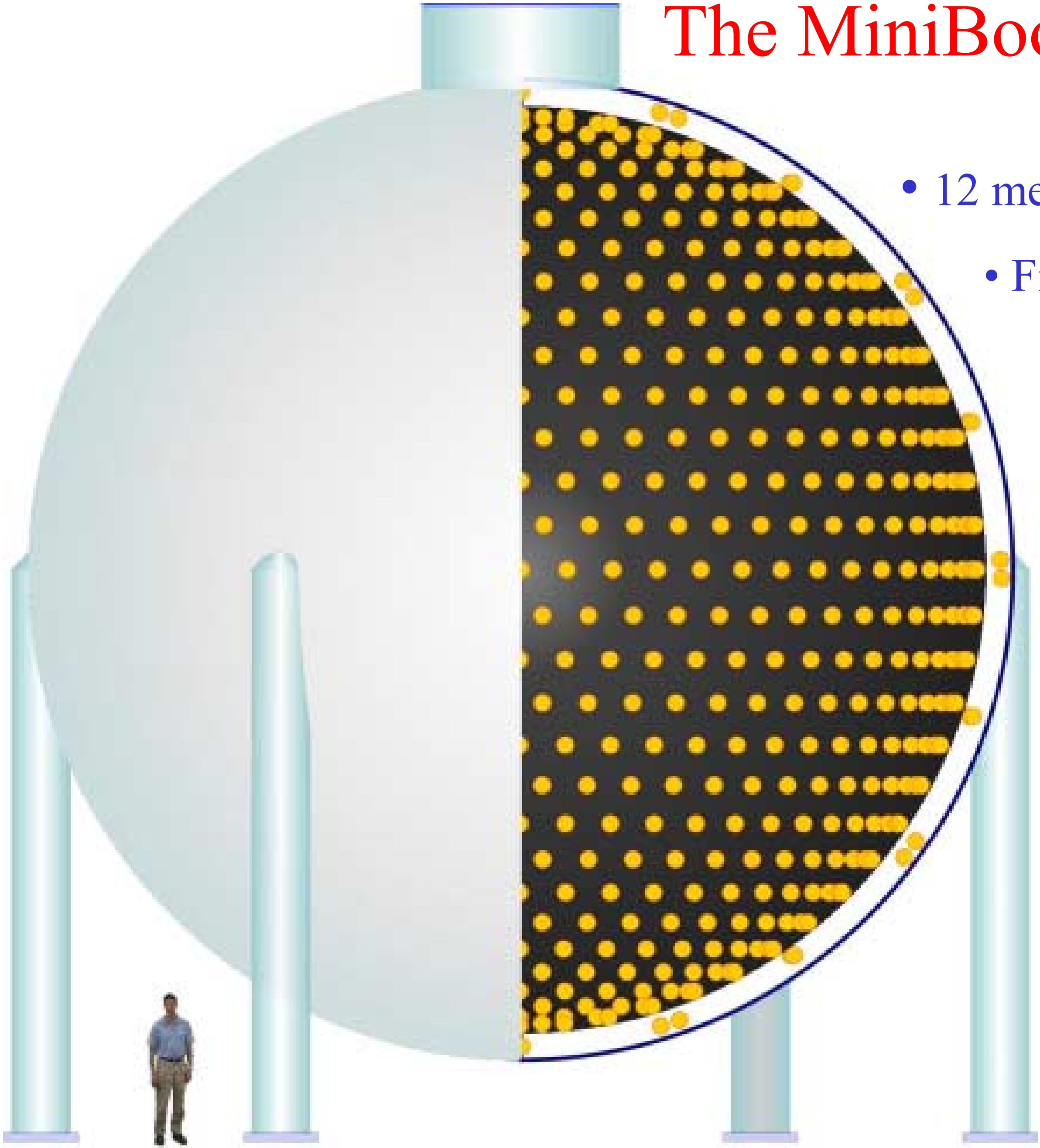
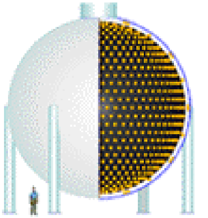
So, the MiniBooNE collaboration was formed to search for ν_e appearance in a ν_μ beam at Fermilab.

MiniBooNE consists of about 60 scientists from 14 institutions.

The MiniBooNE Detector



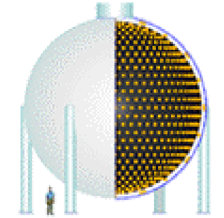


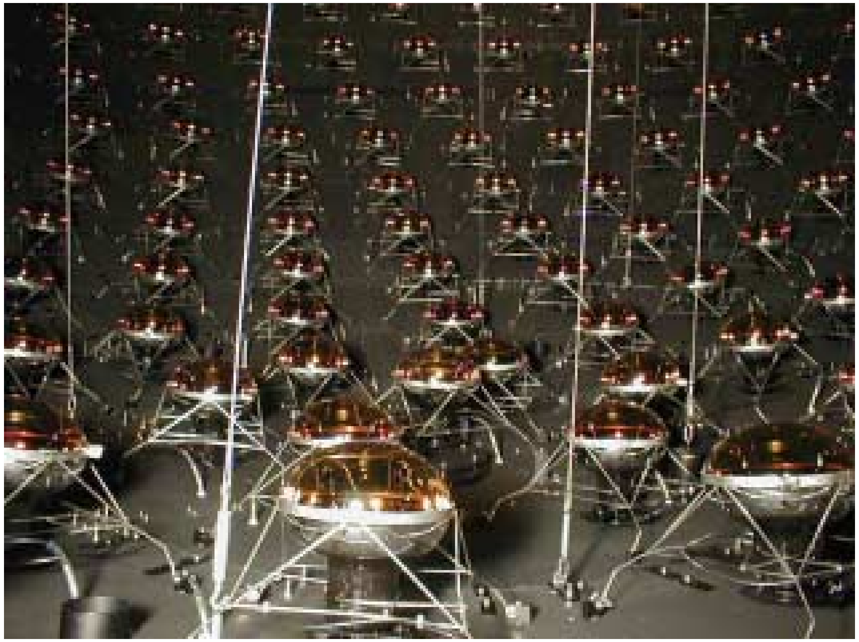
- 12 meter diameter sphere
  - Filled with 950,000 liters of mineral oil
    - Light tight inner region with 1280 photomultiplier tubes
    - Outer veto region with 240 PMTs.

Neutrino interactions in oil produce:

- Prompt Čerenkov light
- Delayed scintillation light

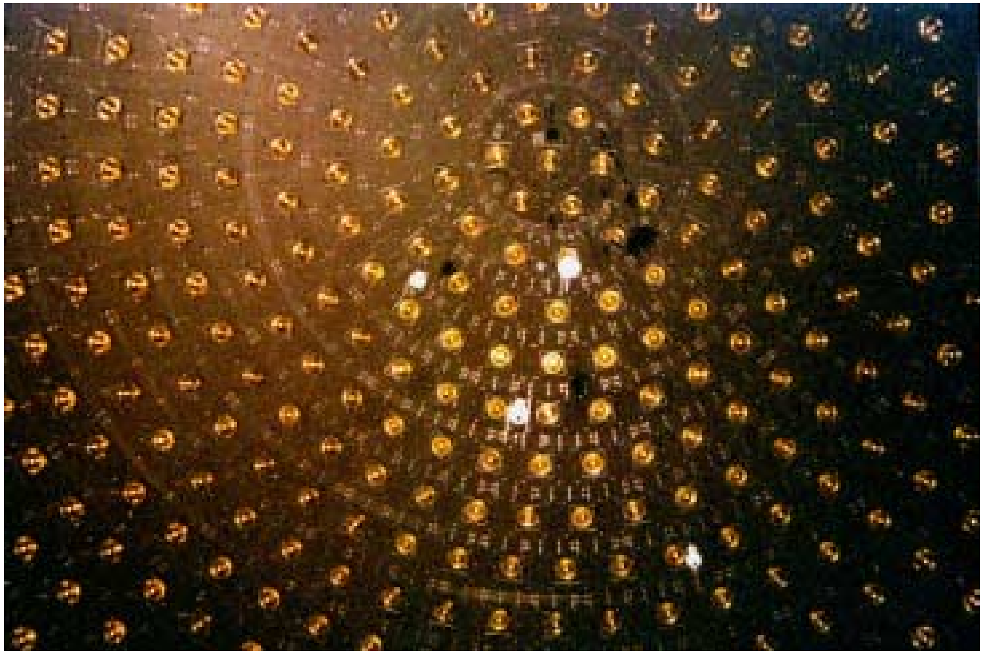
Inside the MiniBooNE Detector

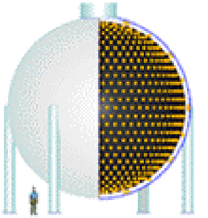




PMTs at the bottom of the detector just before sealing up the inner region.

View of the top polar cap showing laser calibration flasks.





The MiniBooNE Neutrino Beam

Start with a very intense 8 GeV proton beam from Fermilab's Booster.

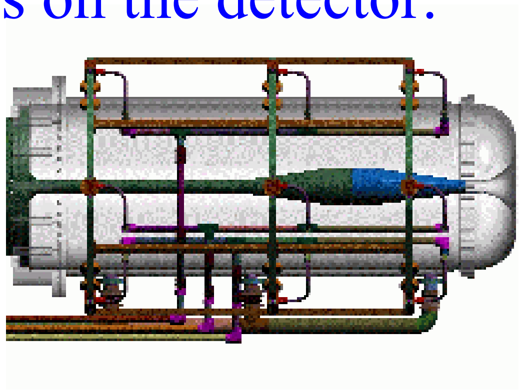
The beam is delivered to a 71 cm long Be target.

In the target primarily pions are produced, but also some kaons.

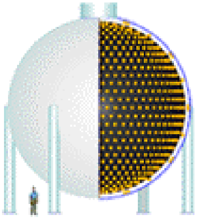
- Charged pions decay almost exclusively as $\pi^{\pm}\rightarrow\mu^{\pm}\nu_{\mu}$.
- The decays $K^{\pm}\rightarrow\pi^{0}e^{\pm}\nu_{e}$ and $K_{\mathrm{L}}\rightarrow\pi^{\pm}e^{\mp}\nu_{e}$ contribute to background.

A toroidal field horn focuses the charged particles on the detector.

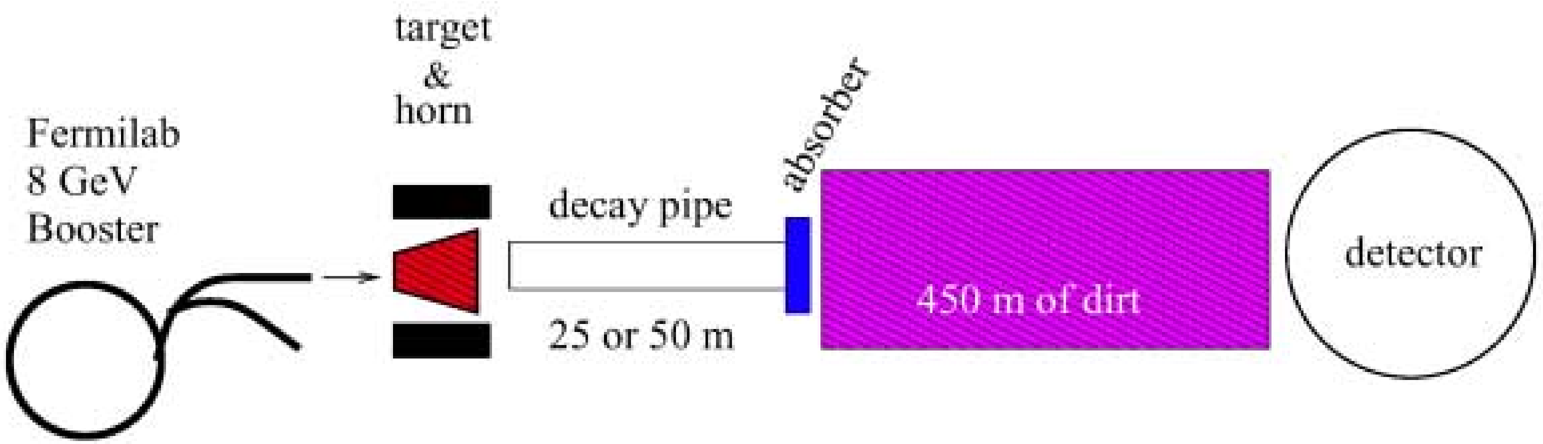
- Initially positive particles will be focused selecting ν,
- but the horn current can be reversed to select $\bar{\nu}$.
- Increases neutrino intensity by an order of magnitude.



The MiniBooNE Beam (Continued)



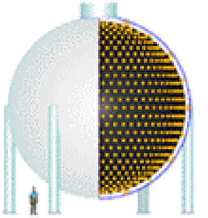
The horn is followed by a decay region of 25 or 50 m.



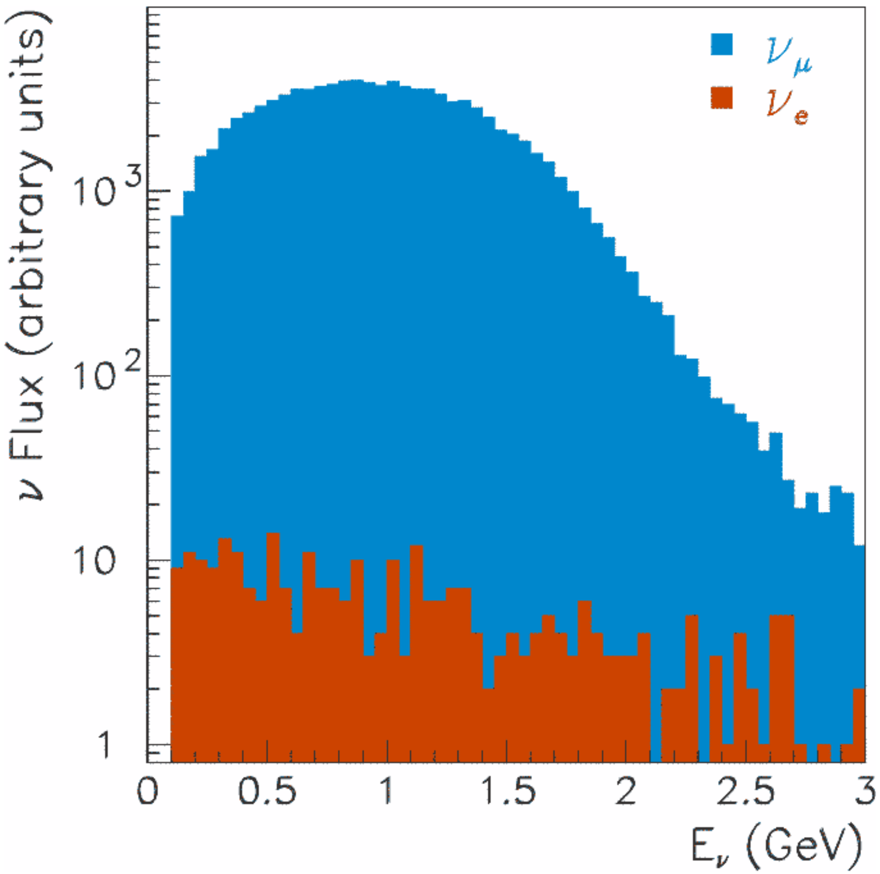
The decay region is followed by an absorber and 450 m of dirt, beyond which only the neutrino component of the beam survives.

Switching between 25 and 50 m decay length helps us understand the ν_e background from μ decay.

Neutrino Flux at the Detector

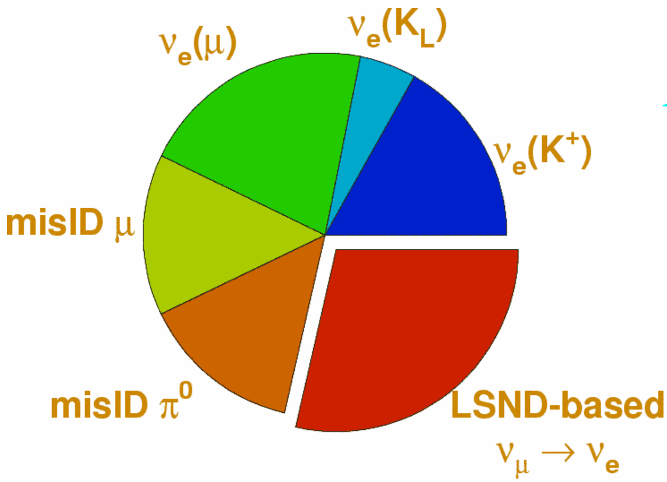


The L/E is designed to be a good match to LSND at ~1 m/MeV.

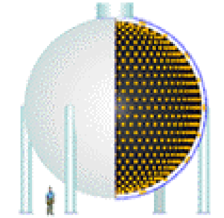


From beam simulations we can see that the expected intrinsic ν_e flux is small compared to the ν_μ flux.

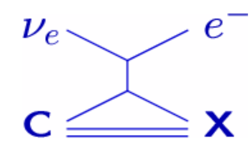
But it is significant compared to the expected oscillation signal.



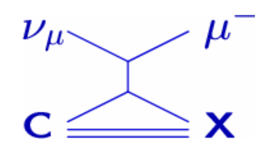
Approximate number of events expected in MiniBooNE with two years of running.



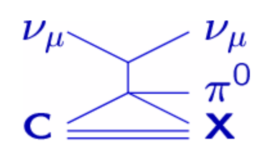
Intrinsic ν_e background: 1,500 events



μ mis-ID background: 500 events

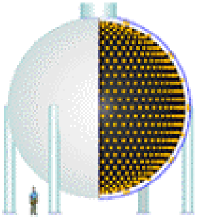


π^0 mis-ID background: 500 events



LSND-based $\nu_\mu \to \nu_e$: 1,000 events

Particle Identification: μ, e and π^0

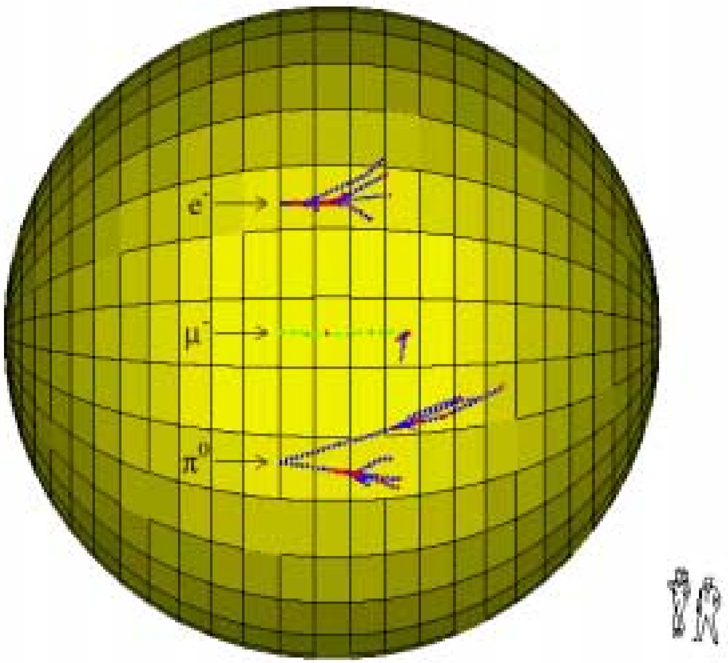


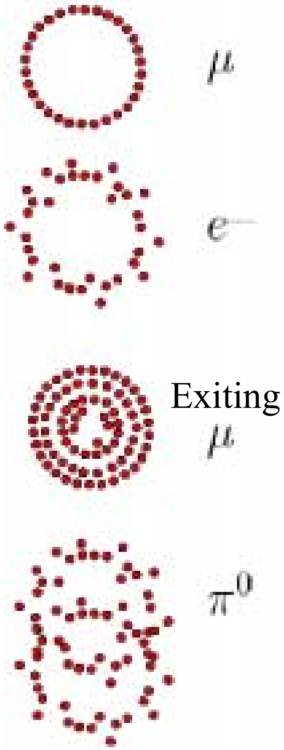
Particle ID is based on ring id, track extent, ratio of prompt/late light signatures substantially different from LSND

factor 10 higher energy and baseline
and neutron capture does not play a role

Fuzzy rings distinguish electrons from muons.

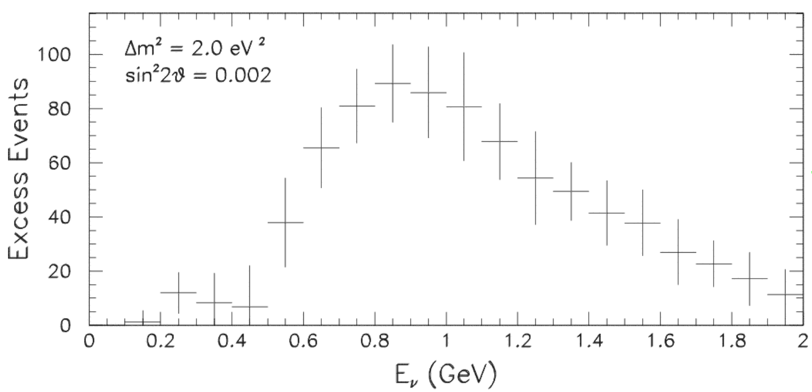
π^0 from neutral current interactions typically look like 2 electrons, but infrequently the two rings overlap and appear as one.

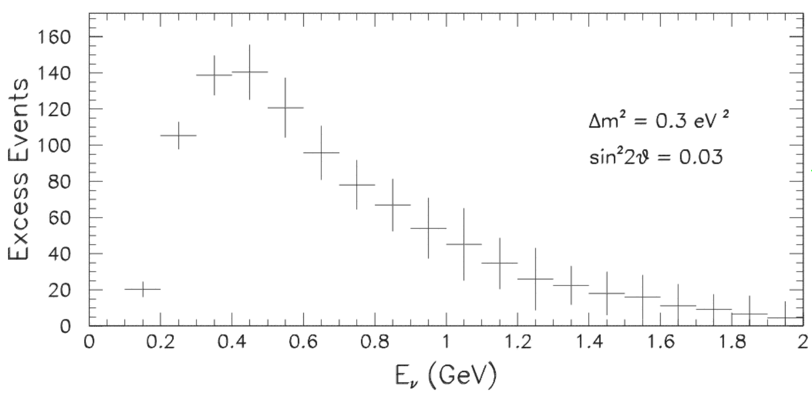


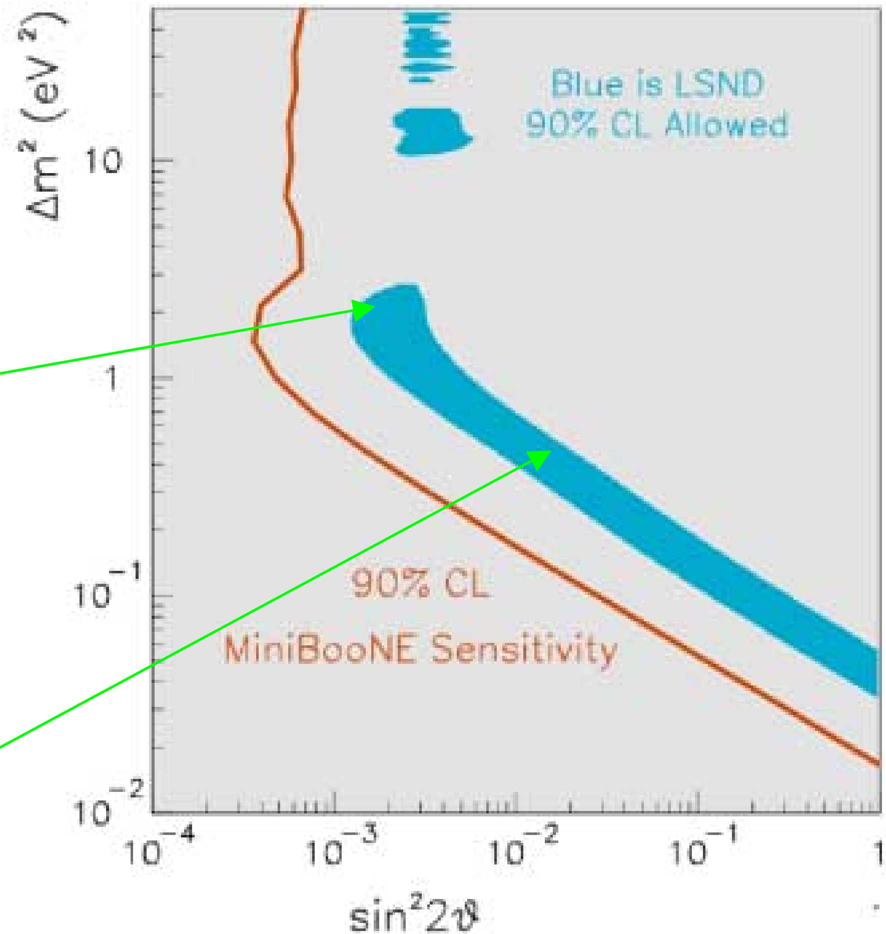


MiniBooNE Sensitivity to LSND

With two years of running MiniBooNE should be able to completely include or exclude the entire LSND signal region.



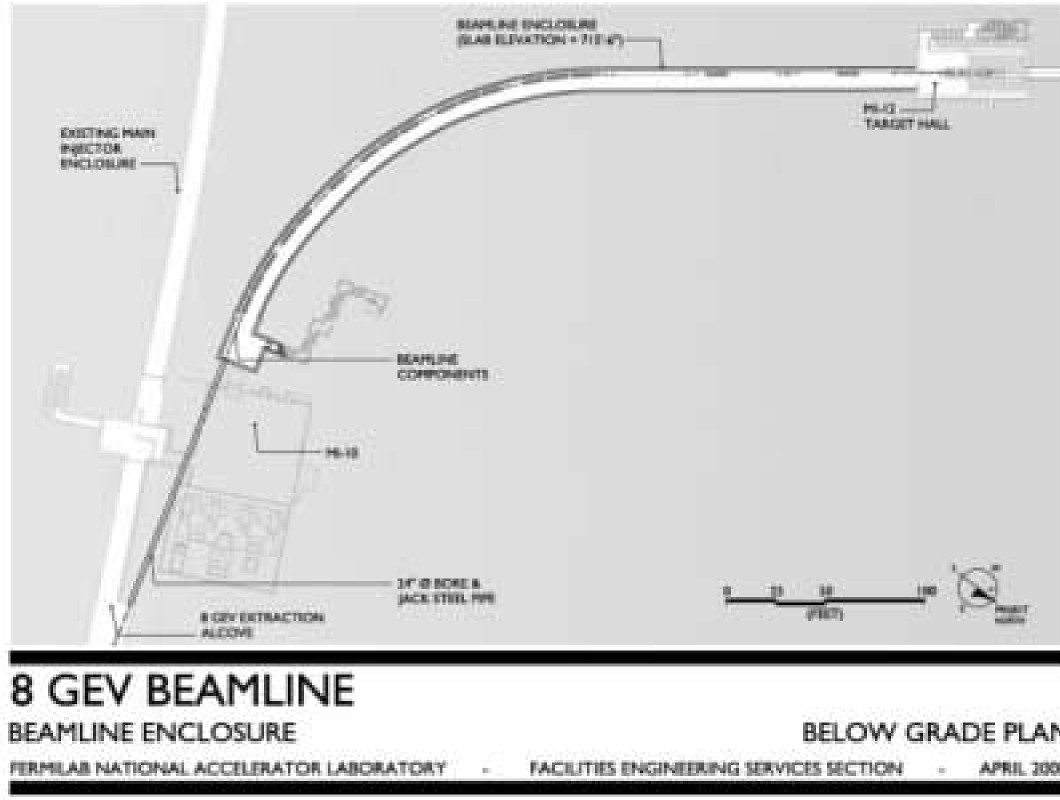




MiniBooNE Status

Civil Construction

MiniBoone requires a new beamline to transfer beam from the Booster to our production target.



We expect to construction to be completed by January 1, and beam late Spring 2002.

MiniBooNE Status

Focusing Horn

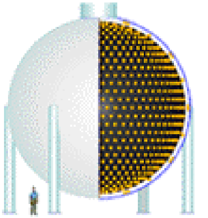
Horn assembly is complete and testing is underway.

The horn will be tested for 20 million pules or 10% of its required lifetime.

Initial testing shows no problem with the horn.

MiniBooNE Status

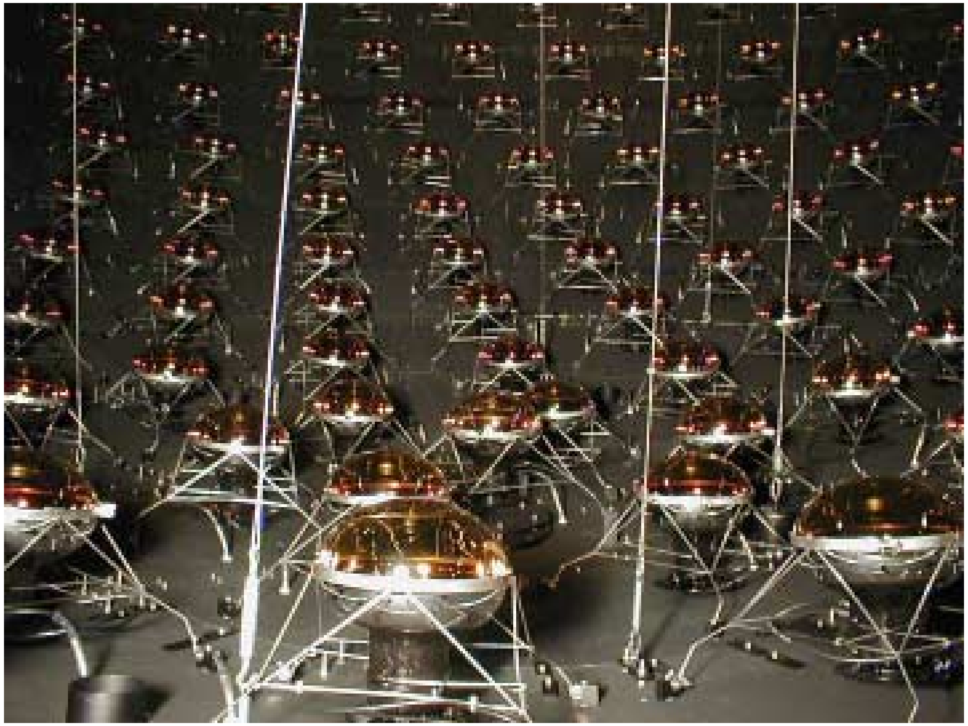
The Detector



PMT installation completed in October.

We will begin filling the tank with oil on Monday!

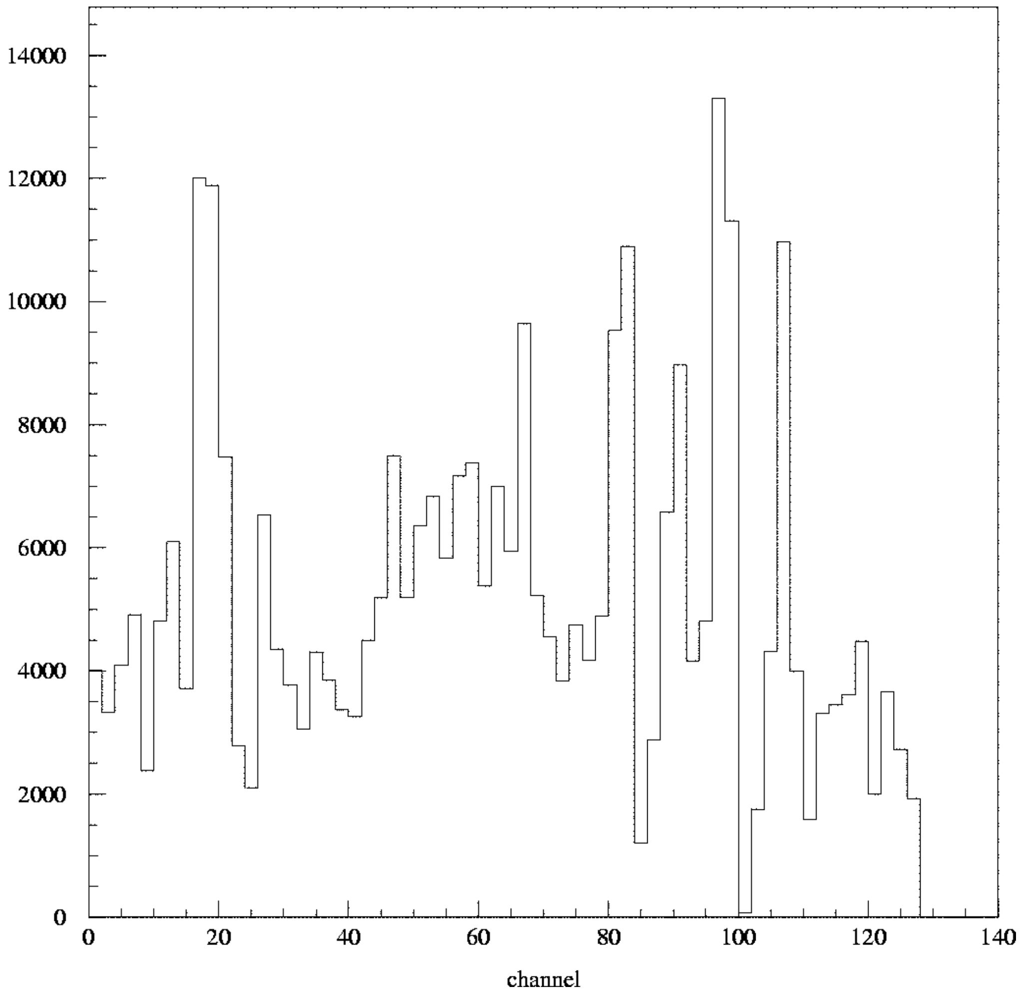
Following the tragedy at SuperK we have begun studies of single tube implosion.

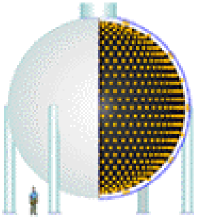


Early calculations suggest that with our 8 inch tubes and 12 meter depth that a implosion induced shock wave will not destroy other tubes.

MiniBooNE Status

The DAQ

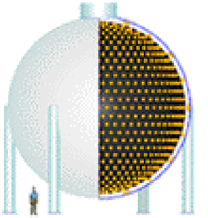




The DAQ is functioning.

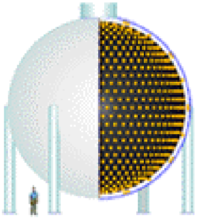
We just successfully completed a detector challenge, demonstrating the full data chain, from tubes to tape, works.

Analysis Plan



- The analysis plan is not yet set in stone.
- It will be a blind analysis.
  - Potential electron neutrino events will be sequestered.
  - The “box” will be gradually opened (10%, 50%, 100%) to allow us to correct glaring flaws in the analysis while maintaining low bias.
- We will be conducting a “data challenge” in the next several months to test analysis techniques on simulated data.

Conclusions



- We are on target to start taking data in spring 2002.
- We will run for two years in ν mode with a total of 10^{21} protons on target.
- With this data we should be able to confirm or rule out the full high Δm^2 oscillation range of LSND.
- We are studying several other possible ν physics topics.
  - $\sin^2\theta_W$
  - Supernova neutrinos
  - The Karmen timing anomaly
- We may also run for two years in $\bar{\nu}$ mode.
- Possible upgrade to BooNE, a two detector experiment to carefully measure Δm^2.